2. Binary Compounds with Variable Valence

Many elements have more than one possible valence - these are called variable valence. Some common variable valence elements are outlined in the following table:

Possible Valences	I or II	II or III	II or IV	III or V	II or IV or VI
Elements	copper (Cu) mercury (Hg)	iron (Fe)	silicon (Si) germanium (Ge) tin (Sn) lead (Pb)	nitrogen (N) phosphorus (P) arsenic (As) antimony (Sb) bismuth (Bi)	sulfur (S)

In binary compound, a variable valence element will come first in the formula. The second element will always have its predictable valence. <u>There are three systems for naming binary compounds with variable valence.</u>

A. IUPAC System (Stock System, International System, Roman Numeral System)

In the name, the valence is given in roman numerals in brackets following the first element. Only the first element will have a variable valence; the second will have the predictable valence from its position in the periodic table.

Writing Formulae from Names

The formulae are written as before, by crossing valences. The variable valence is given in the name.

copper (II) chloride arsenic (III) sulfide sulfur (IV) fluoride lead (II) oxide

Writing Names from Formulae

These are written as before, but with the valence of the first element included in brackets. It may be necessary to back-cross the valences to figure out which valence was used.

PCl_3 PCl_5 $SnBr_2$ $SnBr_4$

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B. "ous-ic" System

This system only works for metals elements with two possible valences. It uses the Latin names of some elements, from which their symbols were derived (the symbols should help indicate the Latin name).

Element	copper (Cu)	iron (Fe)	lead (Pb)	tin (Sn)	gold (Au)
Latin Name	*cuprum*	*ferrum*	*plumbum*	*stannum*	*aurum*

** the **lower** valence of the first element uses the suffix **"-ous"**
** the **higher** valence of the first element uses the suffix **"-ic"**

Writing Formulae from Names

The suffix indicates whether the higher or lower valence is used, then the formulae are written by crossing the valences as usual.

cupric oxide stannous chloride plumbic bromide ferrous iodide

Writing Names from Formulae

The appropriate suffix must be used for the first element, depending on whether it has the higher or lower possible valence. The formula may need to be back-crossed to see which valence was used.

$PbCl_2$ $PbCl_4$ FeO Fe_2O_3

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C. Prefix System

This system is used for compounds composed of non-metals. A prefix is used to indicate the actual number of atoms of each element in a compound when one of the elements has a variable valence.

Writing Formulae from Names

The prefixes give the number of atoms of each type. There is no crossing of valences required.

silicon tetrachloride nitrogen triiodide dinitrogen trioxide sulfur hexafluoride

Writing Names from Formulae
The appropriate prefix must be used for each atom in the compound. If only one atom of the first element is present, the prefix "mono" is left out. When a prefix ending with "o" or "a" is followed by "oxide", omit the "o" or "a": write "tetroxide", not "tetraoxide".

NO_2 PCl_3 P_2O_5 As_2S_3

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3. Peroxides

A peroxide is a compound that contains one more oxygen atom than would be expected from the formula writing rules. They are usually formed with oxygen and an atom from group 1 (I A).

Writing Formulae from Names
Write the correct formula for the oxide of the element, and reduce to lowest terms if necessary. Then, **add one oxygen** to the formula (increase its subscript by 1), and **do not reduce the formula to lowest terms.**

sodium peroxide hydrogen peroxide potassium peroxide

Writing Names from Formulae
You must recognize that a compound is a peroxide when it contains oxygen, and when you back-cross the valences and find that they are incorrect.

Li_2O_2 K_2O_2 Cs_2O_2

______ ______ ______

4. Gases

The Noble Gases are monatomic, meaning they exist as single atoms. The elementary gases (indicated on your periodic table) are diatomic, meaning they exist as two atoms bonded together.

nitrogen gas argon gas neon gas

Two other gases that must be memorized are **ammonia (NH_3)** and **methane (CH_4).**

5. Inorganic Acids

All acids contain at least one atom of hydrogen. Each acid has two names, one for when it is a pure substance, and one for when it is an acid (dissolved in water). Both names must be learned.

A. Binary Acids

These are acids that contain two types of atoms, hydrogen and something else. As a pure substance, a binary acid is named the same way as any binary compound. As an acid dissolved in water, the name is **"hydro_____ic acid"**.

Writing Formulae from Names

Either name will indicate what the other element is in addition to hydrogen. Cross the valences as usual to write the formula.

hydrogen chloride   hydrosulfuric acid   hydrogen bromide   hydroiodic acid

Writing Names from Formulae

You must recognize from the fact that there are hydrogen atoms present that these compounds are acids, and write the appropriate name as indicated. There is no need to back-cross valences.

HF	H_2Se	HCl	HBr
________ (pure substance)	________ (acid name)	________ (pure substance)	________ (acid name)

B. Oxy-Acids

An oxy-acid is an acid which contains hydrogen, oxygen, and one other atom type. There are six root oxy-acids that must be memorized:

Formula	Name as a Pure Substance	Name as an Acid
$HClO_3$	hydrogen chlorate	chloric acid
HNO_3	hydrogen nitrate	nitric acid
H_2SO_4	hydrogen sulfate	sulfuric acid
H_2CO_3	hydrogen carbonate	carbonic acid
H_3PO_4	hydrogen phosphate	phosphoric acid
CH_3COOH	hydrogen acetate	acetic acid

B. Families of Acids and Their Radicals

The first 5 root oxy-acids each serve to generate an entire family of acids and radicals. You must learn the pattern so you can use the radicals in formula writing. **Note that although the number of oxygen atoms change, **the charge (valence) stays the same.**

Acid Formula	Acid Name	Radical Formula	Radical Name
$HClO_3$	chloric acid	ClO_3^-	chlorate

Acid Formula	Acid Name	Radical Formula	Radical Name
HNO_3	nitric acid	NO_3^-	nitrate

Acid Formula	Acid Name	Radical Formula	Radical Name
H_2SO_4	sulfuric acid	SO_4^{2-}	sulfate

Acid Formula	Acid Name	Radical Formula	Radical Name
H_2CO_3	carbonic acid	CO_3^{2-}	carbonate

Each new oxy-acid has a family of acids and radicals like the root oxy-acids:

Acid Formula	Acid Name	Radical Formula	Radical Name
H_3SbO_4	Antimonic acid	SbO_4^{3-}	antimonate

Each of these radicals can be used in formula writing, with the usual rules.

D. Miscellaneous Radicals

Finally, there are three miscellaneous radicals that must be memorized:

- **hydroxide radical** **OH^-**
- **permanganate radical** **MnO_4^-**
- **ammonium radical** **NH_4^+** (this is the only positively charged radical)

These radicals are used to write formulas the in same way as all the others.

Acid Formula	Acid Name	Radical Formula	Radical Name
H_3PO_4	phosphoric acid	PO_4^{3-}	phosphate

C. Related Radicals

Four of the oxy-acids have relatives, related by their position in the periodic table.

Group 14 (IV A)	Group 15 (V A)	Group 16 (VI A)	Group 17 (VII A)
(C) H_2CO_3 carbonic acid	(P) H_3PO_4 phosphoric acid	(S) H_2SO_4 sulfuric acid	(Cl) $HClO_3$ chloric acid
(Si)	(As)	(Se)	(Br)
(Ge)	(Sb)	(Te)	(I)

Each new oxy-acid forms a radical like the root oxy-acids:

- **silicate:**
- **antimonate:**

These radicals can be used in formula writing, with all the usual rules.

6. Compounds Containing Radicals

A radical is another name for a polyatomic ion. The radical behaves as a unit in a chemical reaction, forming compounds with another atom.

A. Radicals from Oxy-Acids

The six root oxy-acids form radicals when the hydrogen atoms are removed. The valence is always negative, and is equal to the number of hydrogen atoms lost by that acid. They must be memorized.

Acid Formula	Acid Name	Radical Formula	Radical Name
$HClO_3$	chloric acid	ClO_3^-	chlorate radical
HNO_3		NO_3^-	
H_2SO_4		SO_4^{2-}	
H_2CO_3			
H_3PO_4			
CH_3COOH		CH_3COO^-	acetate radical

Radicals form compounds with other atoms, both fixed valence and variable valence. All the regular binary compound rules apply.

Writing Formulae from Names

Write the symbols for the first atom and the radical. Treat the radical as a single unit, using the charge as the valence (the sign does not need to be considered), and crossing valences as usual. If the radical needs a subscript, it must be bracketed.

sodium sulphate | copper (II) sulphate | ferrous phosphate | tin (II) nitrate

Writing Names from Formulae

The radicals must be recognized and named correctly. If a variable valence element is involved, it may be necessary to back-cross to find which valence was used.

K_2CO_3 | $Ca(NO_3)_2$ | $Fe_3(PO_4)_4$ | $Cu(CH_3COO)_2$

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